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ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

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AGARD ADVISORY REPORT 312

Technical Evaluation Report on the Flight Mechanics Panel Symposium on Aircraft Ship Operations

(Le Couple Aéronef-Navire dans les Opérations)

This Advisory Report was prepared at the request of the Flight Mechanics Panel of AGARD.

NORTH ATLANTIC TREATY ORGANIZATION

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Technical Evaluation Report on the Flight Mechanics Panel Symposium on Aircraft Ship Operations

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by

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This Advisory Report was prepared at the request of the Flight Mechanics Panel of AGARD.

North Atlantic Treaty Organization
Organisation du Traité de l'Atlantique Nord

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Preface

The interest in the use of shipborne aircraft is widespread among NATO countries. Major weapons systems like aircraft carriers with conventional fixed-wing aircraft, VSTOL aircraft or helicopters embarked, are operated by the United States, the United Kingdom, France, Italy and Spain. Nearly all NATO countries employ various classes of smaller ships as helicopter platforms for amphibious assault, anti-submarine warfare or search and rescue.

The deployment of aircraft on board ships presents unusual and difficult technical and operational problems. Considering the multi-national interest in aircraft/ship operations it was considered meaningful and timely for the Flight Mechanics Panel to sponsor a symposium on this topic. This symposium considered problems of mutual interest connected with fixed and rotary wing aircraft operations from ships, and the application of new technology to enhance such operations.

The Symposium reviewed and assessed the current problems and possible future progress in:

— The ship environment in terms of wind, temperature, precipitation, turbulence and deck motion.

— Guidance, Controls and Displays, primarily in the approach and landing phase.

— Flight Test and Simulation Techniques.

— Launch, Recovery and Handling Systems Developments.

— Operational/Pilot Views and Future Developments.

This Technical Evaluation Report evaluates the presentations and discussions in each session, draws relevant conclusions and makes recommendations for future activities in this area.

Préface

La mise en oeuvre d'aéronefs embarqués suscite un vif intérêt dans les différents pays membres de l'OTAN. Les systèmes d'armes majeurs que sont les porte-avions dotés soit de chasseurs conventionnels à voilure fixe, soit d'avions VSTOL, soit d'hélicoptères embarqués, sont en service aux Etats-Unis, au Royaume-Uni, en France, en Italie et en Espagne. La quasi-totalité des pays membres de l'OTAN utilise divers type de navires de moindre tonnage en tant que porte-hélicoptères pour l'assaut amphibie, la guerre anti-sous-marine et les missions de recherche et sauvetage.

Le déploiement d'avions embarqués à partir de bâtiments de guerre pose des problèmes techniques et opérationnels spécifiques et difficiles. Etant donné l'intérêt multi-national manifesté pour les opérations aéronef-navire, le Panel a jugé opportun et positif d'organiser un symposium sur ce sujet. Le symposium a examiné certains problèmes d'intérêt mutuel concernant la mise en ouevre de aéronefs embarqué à voilure fixe et à voilure tourante, ainsi que les applications possibles des nouvelles technologies pour accroître l'efficacité de telles opérations.

Le symposium a examiné et évalué les problèmes actuels qui se posent et une évolution future possible dans les domaines suivants:

— l'environnement navire, sous les aspects vent, température, précipitations, turbulence et mouvements du pont.

— le guidage, les commandes et la visualisation, principalement lors des phases de d'approche et d'atterrissage.

— les techniques de simulation et d'essais en vol.

— le développement de systèmes de lancement, de recueil et de manutention.

— les aspects opérationnels/points de vue des pilotes, et les développements futurs.

Ce Rapport d'Evaluation Technique évalue les présentations et les discussions qui ont eu lieu lors de chaque session, en tire les conclusions qui s'imposent et soumet des recommandations concernant des activités futures dans ce domaine.

Flight Mechanics Panel

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Introduction

The combination of ships and aircraft into a war fighting system may be the best possible exemplification of the word synergism. Certainly, worldwide interest in the use of shipborne aircraft as a major weapons system is very broad. Many NATO countries operate fixed wing aircraft from ships. By 1988, as the AGARD symposium on the Aircraft Ship Interface was being planned, the United States, England, France, an Italy all had fixed wing capable aircraft carriers. Since then Spain has been added to the list with the completion of the Principe de Asturias and France has laid plans for both new carriers and new carrier-based fixed wing aircraft.

Additionally, the use of ships as helicopter platforms is extensive in the NATO community and brings another import dimension to the aircraft/ship interface issue. The helicopter is fast approaching a half century of service as a weapons system. From humble beginnings in World War II, largely in the roles of observation platforms and search and rescue vehicles, rotorcraft have evolved to a principal force in the modern battle scenario. In the war at sea, the helicopter forms an integral part of a task force capable of launching devastating firepower at surface and subsurface targets. Aided by communications and data links, the helicopter effectively becomes the extended sensor of the task force itself. Technology has made the helicopter into a tank killer, troop transport and night observation platform. In the most unlikely arena, air-to-air combat, modern weaponry has shown the helicopter to be effective against even high performance tactical aircraft. Certain weapons and tactics have permitted the exploitation of the helicopter's unique ability to point and aim rapidly. These factors coupled with the low comparative cost of the helicopter, has given it a significant role in many national arsenals. Thus, it seemed that both fixed wing and rotary wing aviation deserved equal billing in the Aircraft/Ship Interface Symposium which is the subject of this Technical Evaluation Report. This symposium was held in Seville, Spain, from 20 to 23 May 1991 and was the first symposium sponsored by the AGARD Flight Mechanics Panel devoted to this topic.

Review of the Technical Program

The symposium contained twenty-five presentations grouped under the following six session topics:

Session I	-	Keynote Addresses
Session II	-	Ship Environment
Session III	-	Guidance, Controls, and Displays
Session IV	-	Flight Test and Simulation Techniques
Session V	-	Launch, Recovery, and Handling Systems Development
Session VI	-	Operational Views (from the pilot) and Future Developments

The welcoming remarks by ADM Martin-Graniza and the keynote addresses by ADM Parcells and ADM Burn set the stage for not only this symposium but for the future of naval airpower. These speakers reflected on common issues. Instability and turmoil are growing throughout the world and the decrease in superpower confrontations with the attendant decline in defense budgets will make it hard to maintain an essential defense posture. These issues are further compounded by the suspicion that the Soviets will not change their military posture very much, very quickly and will be driven to sell Soviet weaponry to third world nations in a search for hard currency. It is likely that it is a neutral environment in which crises will most likely develop. It is also likely that combined airpower and seapower will provide the cost effective solution. These conditions point to the importance of a naval air force. As budgets decline, the highest order of imagination and scientific

application will be required to develop the applicability and availability of naval air power in an affordable manner. As refined as the state-of-the-art is currently, much remains to be done.

Efforts are needed to provide improvements in the following areas:

- Aircraft design penalties extracted by the need to operate from ships.
- Air vehicle agility in the landing and takeoff phases of flight.
- Landing aids to permit all weather operations, including fully automatic landing systems for all classes of aircraft.
- Aircraft capable of multi-functions to permit a reduction in the number of aircraft that must be carried to make a ship combat capable.
- Lighter, cheaper and less labor intensive ship hardware, particularly catapults and arresting gear.

The technical program itself was represented by Sessions II through VI. A listing of the papers presented is contained in Appendix I. Several observations are possible from an overview perspective. It is clear that the terms fixed-wing and rotary-wing do not simply represent a functional distinction, but a technical maturity distinction, as well.

By the time of the World War II Battle of Midway, a benchmark in the history of fixed wing military operations, the helicopter was still one year away from its first training duties in the military and nearly two years away from first combat operations. Despite a half century of progress, such a profound technical maturity schism still persists. The papers describing fixed-wing naval aviation technologies presented at Seville were impressive. Topics included deck motion criteria, deck motion predictions and control, automated deck-landing control systems, advanced displays, test and evaluation techniques, structural modeling techniques, advanced V/STOL designs and related ships considerations, and future ship designs. It is reasonable to describe these papers as representing an engineering state-of-the-art which is consistent with the current science and technology base. Further, it is clear that systems engineering is more than a euphemism in fixed wing carrier aviation. Good examples were easy to find, e.g., the integration of the automatic carrier landing function into the F-18 flight control system, the design of the Principe de Asturias from the keel up as an AV-8 support ship, etc.

A highly refined state of systems engineering does not exist in the realm of seaborne rotary-wing aviation, however. Obvious deficiencies were evident. Probably, the most dramatic is in the area of the aerodynamic interaction of ships and helicopters. Although of concern in several areas (e.g., rotor engagement, take-off, etc.), such interaction is particularly troublesome and limiting in the case of landing operations. This area does not receive sufficient design priority in ship construction or does it benefit from modern analytic or experimental tools. In so far as ship design is concerned, the ship's airwake is both critical and largely unknown in the view of several symposium authors. It is interesting to note that one of the few ships in existence which has an airwake that facilitates helicopter operations, the Soviet Kirov, achieved that condition by coincidence. It was simply the by-product of ship radar signature reduction. Another striking feature of the symposium was the lack of papers discussing modern flow characterization technologies in the amplification of full-scale ship airwake measurements. Techniques involving laser and ion flow velocimetry hold great promise for this problem and there are not doubt other technologies that could be exploited. The reliance on ineffective techniques such as smoke studies, tufting, neutral buoyancy bubbles, etc., is unsatisfactory. Also, with the exception of a single paper and a few oblique references, no discussion of sub-scale wind tunnel investigations existed.

Both full-scale and model-scale measurement studies are required to define and solve aircraft/ship operations problems caused by the ship's airwake. The enormous physical size of an aviation-capable ship is the reason why model studies are required to completely document airflow phenomena and

this is also the principal reason why wind tunnel model studies of this problem are so difficult. Previous experiments have been limited to collecting point-by-point velocity and turbulence measurements at a few locations in the wake in small wind tunnels. It took years to report the results. There are indications from existing data that the flow field structure and frequency content are significantly dependent on Reynolds number. Accordingly, any model experiment must be conducted at the highest Reynolds number possible. Reynolds numbers based on ship deck housing height of 10^6 or larger are recommended. The structure of the overall unsteady separated flow and the dynamics of the separated shear layer must be measured by techniques using multiple-point simultaneous mapping of the entire unsteady flow fields. The measurements should provide the strength and track of the vortices shed from the superstructure/deck and the associate turbulence fluctuations in the shear layer, and the frequency content and length scales of the fluctuations. It is important to identify the dominant unsteady separated flow structure which affect the safe operation of aircraft and helicopters on the ships.

A final area related to the aerodynamic interaction of ships and helicopters is flight control technology. This area is highly developed, as we have seen, from fixed-wing carrier aviation and may be the single most important area for near-term gains in improving the performance of rotorcraft in close proximity to a ship. Although a single paper was originally selected for the symposium, none were presented.

I wish to conclude the matter of ship/rotorcraft aerodynamic interface by suggesting that the Advisory Group for Aerospace Research and Development, Flight Mechanics Panel, form a working group to treat this topic. This working group should assess the state-of-the-art of all relevant technical sub-areas and develop a plan for cooperative research and development efforts that would extend essential technologies to a point where ship and rotorcraft designs could be enhanced. I believe that the Seville symposium showed such a working group to be needed. The participation must include, of course, the surface ship community and might logically be conducted in consort with the Fluid Dynamics Panel. It is likely that a plan of action could be a reasonable outcome from the working groups considering the normal two-year time span of the group.

Ship motion represented another area where rotorcraft were severely penalized at sea. Typically deployed from a variety of smaller ships, deck motion dramatically influences the design of these vehicles. The presence at the symposium of a number of naval engineers and architects led to the development of technical interplay between the NATO Naval Armaments Group, Ship Design Group (Group # 6), and the Flight Mechanics Panel. It is recommended that this interface be formalized by charter as soon as possible, so that the momentum of the conference will be preserved.

Conclusion

The value of the conference will surely be in the direction that we choose to take from it. The advancement of sea-borne air power is essential in the future and the conference pointed to several obstacles. These deficiencies should be viewed as an opportunity to develop the technologies with a focus on military effectiveness.

Recommendations

1. Form a Flight Mechanics Panel Working Group on the Aerodynamic Interface of Ships and Rotorcraft in order to influence cooperative technical ventures aimed at developing this area.

2. Formalize the relationship between the NATO AGARD Flight Mechanics Panel and the NATO Naval Armaments Group, Ship Design Group (Group # 6).

Acknowledgement

The author wishes to thank Dr. Thomas T. Huang, Senior Research Scientist at the United States Navy David Taylor Research Center, for his comments on the ship/aircraft aerodynamic interface.

APPENDIX I
FINAL PROGRAMME
FMP SYMPOSIUM
AIRCRAFT/SHIP OPERATIONS
20-23 MAY 1991
SEVILLE, SPAIN

SESSION I: KEYNOTE ADDRESSES
Chairmen, R. Russell (US),
J. Van Doorn (NE)

1. Fixed Wing/Carrier Operations Perspective
RADM P. W. Parcells, Commander, Tactical Wings US Atlantic Fleet (US)

2. Helicopter/STOVL/Ship Operations Perspective
RAMD R. Burn, MoD (UK)

SESSION II: SHIP ENVIRONMENT
Chairmen, J. Lopez Ruiz (SP), S. Baillie (CA)

3. Deck Motion Criteria for Carrier Aircraft Operations
J. H. Pattison, NAVSEASYSCOM
R. R. Bushway, NAVAIRSYSCOM (US)

4. The Aerodynamics of Ship Superstructures
J. V. Healey, Navy Postgraduate School (US)

5. Carbon Dioxide Laser Velocimeter Measurement of Ship Airwake from the Helicopter
D. Carico &. B. Reddy, NAVAIRTESTCEN
C. Dimarzio, Northeastern University (US)

6. Measurement of the Flow Distribution Over the Flight Deck of an Aircraft Carrier
M. Mulero & F. Gomez Portabella, INTA (SP)

7. A New Method for Simulating Atmospheric Turbulence for Rotorcraft Applications
J. Riaz, J.V.R. Prasad, D. P. Schrage, School of Aerospace Engineering, Georgia Institute of Technology (US), & G. H. Gaonkar, Department of Mechanical Engineering, Florida Atlantic University (US)

SESSION III: Guidance, Controls and Displays
Chairmen, F. Abbink (NE),
A. Woodfield (UK)

8. Enhanced Displays, Flight Controls and Guidance Systems for Approach and Landing
G. K. Kessler & R. W. Huff, NAVAIRTESTCEN (US)

9. Integration du Pilotage et des Systemes d'Aide a l'Appointage pur les Operations Embarquees (Integration of Flight and Landing Aid System for Shipboard Operations)
B. Dang Vu & P. Costes, ONERA (FR)

10. Approche et appontage assistes par traitement d'image embarque sur aeronef (Automated Deck-Landing Guidance using Airborne Image Processing)
M. Y. Le Guilloux & R. Feuilloy, SAGEM (FR)

11. Approach and Landing Guidance
    A. J. Smith & E. J. Guiver, RAE (UK)

SESSION IV: Flight Test and Simulation Techniques
Chairmen, J. Appleford (UK), Mr. R. Hilderbrand (US)

12. Analytical Modeling of SH-2F Helicopter Shipboard Operation
    Fu-Shang Wei, Kaman Aerospace Corp. (US)
    E. Baitis & W. Myers, David Taylor Research Center (US)

13. A Review of Australian Activity on Modelling the Helicopter/Ship Dynamic Interface
    A. M.Arney, J. Blackwell, L. P. Erm & N. E. Gilbert (AUSTRALIA)

14. Helicopter-Ship Analytic Dynamic Interface Analysis
    B. Ferrier & F. Thibodeau, Canadair (CA)

15. EH-101: Ship Interface Trials - Flight Test Programme and Preliminary Results
    R. Longobardi & B. Paggi, Agusta (IT)

16. Determination of Limitations for Helicopter Ship-Borne Operations
    R. Fang, NLR (NE)

17. Evaluating Fixed Wing Aircraft in the Aircraft Carrier Environment
    C. P. Senn, NAVAIRTESTCEN (US)

18. United Kingdom Approach to Deriving Military Ship Helicopter Operating Limits
    B. A. Finlay, A & AEE Boscombe Down (UK)

SESSION V: Launch, Recovery and Handling Systems Development
Chairwoman: M-H. Fouche (FR)
Chairman: Dr. A. Filisetti (IT)

19. United States Navy Ski Jump Test Experience and Future Applications
    C. P. Senn & T. C. Lee, III,
    NAVAIRTESTCEN
    J. W. Clark, Jr., NAVAIRDEVCEN (US)

20. Helicopter Handling On-Board Ships: Experience and New Developments
    T. C. Craig, McTaggart and Scott (UK)
    W. R. M. Reimering, Rotterdamsche Droogdok Maatschappij (NE)

21. Modelisation Dynamique de l'Avion sur ses Atteriseurs et Validation par Franchissement d'un Diedre (Modeling of Landing Gear During Catapult Phase)
    M. D. Fleygnac & E. Bourdais, Dassault Aviation (FR)

22. Some Implications of Advanced STOLV Operations from Invincible Class Ships
    P. Knott & K. Ainscow, British Aerospace (UK)

SESSION VI: Operational Views (from the pilot) and Future Developments
Chairmen, P. Hamel (GE), D. Agneessens (BE)

23. Environmental Limitations in Helicopter/Ship Operations
    D. Falcinelli (IT)

24. Fixed Wing Night Carrier Aero-Medical Considerations
    J. C. Antonio, Air Development Squadron FIVE (US)

25. Aircraft Options for a Revolution at Sea: 2030
    J. C. Biggers, ARC Professional Services &
    P. A. Silvia, David Taylor Research Center (US)

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Guidance and control	Amphibious operations

14. Abstract

Worldwide interest in the use of shipborne aircraft as a major weapons system is very broad. Many NATO countries operate fixed wing aircraft from ships. Additionally, the use of ships as helicopter platforms is extensive in the NATO community and brings another import dimension to the aircraft/ship interface issue. Thus, it seemed that both fixed and rotary wing aviation deserved equal billing in the Aircraft/Ship Interface Symposium which is the subject of this Technical Evaluation Report. This Symposium was held in Seville, Spain, from 20th to 23rd May 1991 and was the first Symposium sponsored by the AGARD Flight Mechanics Panel devoted to this topic.

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